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Remote Automatic Weather Station for Resource and Fire Management Agencies

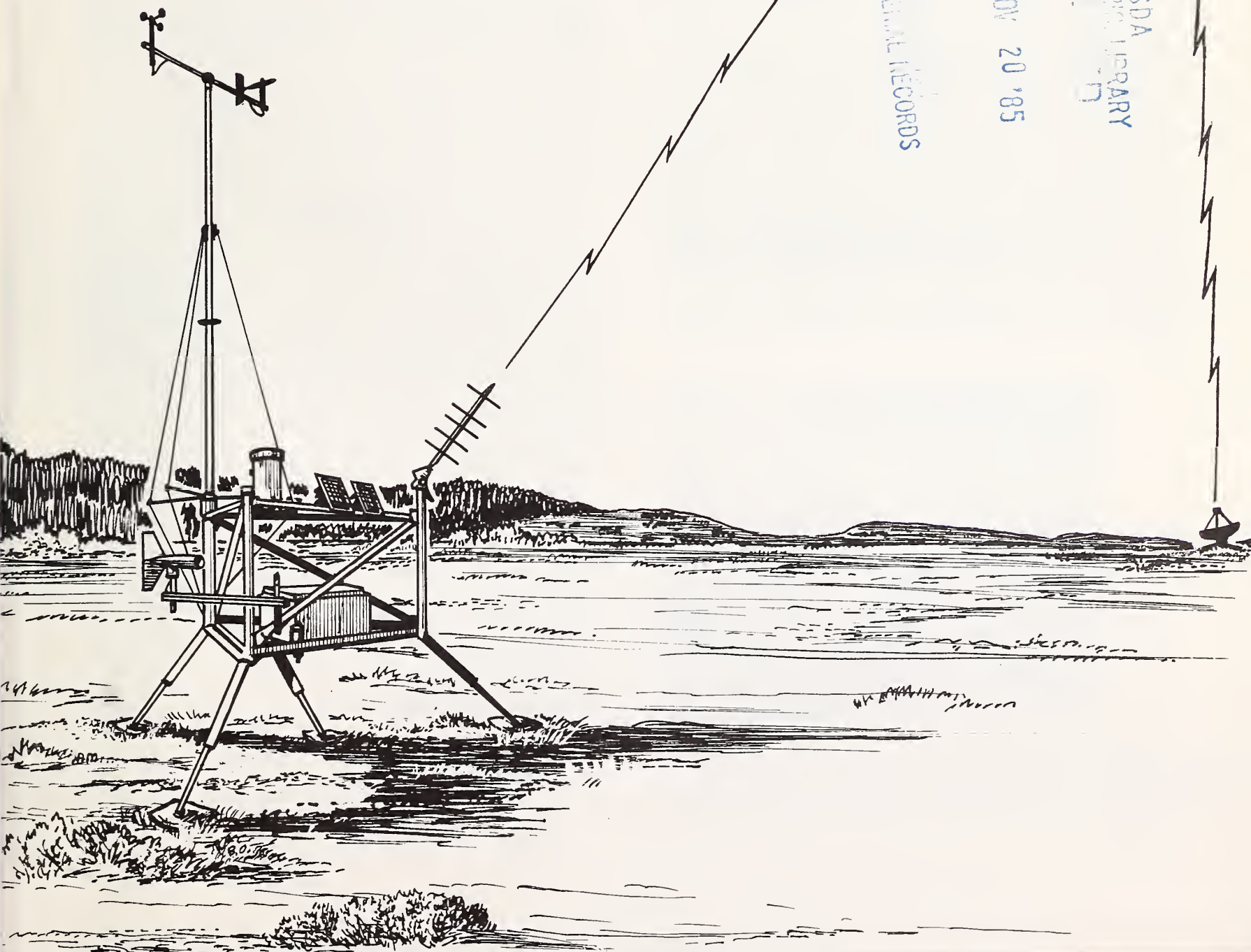
John R. Warren
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RESEARCH SUMMARY

Remote Automatic Weather Stations (RAWS) have been developed and are now operational across the nation in a variety of geographical areas. RAWS acquire, process, store, and transmit accumulative precipitation, wind-speed, wind direction, air temperature, fuel temperature, relative humidity, barometric pressure, and battery voltage. RAWS will operate unattended for 6 months or longer; batteries recharged by solar panels furnish power. Weather data are retransmitted via the Geostationary Operational Environmental Satellite (GOES) to the National Environmental Satellite Service (NESS), Wallops Island, Va., receiving station, and subsequently stored at the World Weather Building in Maryland. Data may be retrieved by direct dial, dedicated phone lines, or through AFFIRMS. Small earth terminals (receiving stations) are also commercially available for direct reception from GOES.

RAWS fulfill a long standing need for automatic weather data acquisition from remote sites. RAWS can be used nationwide as part of the National Fire-Danger Rating System, in clusters over an area of concern, for research, or individually for local weather.

RAWS have been field proven, are operational, and are currently available from two qualified commercial manufacturers.

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Remote Automatic Weather Station for Resource and Fire Management Agencies

INTRODUCTION

RAWS is an acronym for Remote Automatic Weather Station(s). The RAWS discussed in this report were developed over 3 1/2 years by USDA Forest Service(FS) and the U.S. Department of Interior, Bureau of Land Management (BLM) electronics engineers (the authors) and by LaBarge Electronics Division, Tulsa, Okla. The development was a cooperative effort utilizing the experience and knowledge of the engineers involved and a complete sharing of development, test, and operational results. Through this cooperative, interagency approach, duplicative, redundant efforts and costs were avoided. Cost savings and commonality of stations, data, and spares have been achieved.

The RAWS are remote. They may be installed in essentially any geographic region or climate and in any terrain. The only restrictions are that there must be line of sight from the antenna to the Geostationary Operational Environmental Satellite (GOES), and there must be enough sunlight to maintain the battery charge via the solar panels.

The RAWS are automatic. Once installed and activated, they automatically acquire, process, and store local weather data for subsequent transmission. No personal attention, access, or instrument readings are required.

The RAWS are weather stations. The RAWS acquire, process, store, and transmit the following data:

- accumulative precipitation-rain gage (RG)
- wind direction (10 minutes filtered or average) (WD)
- windspeed (10 minutes filtered or average) (WS)
- air temperature (AT)
- fuel temperature (FT)
- relative humidity (RH)
- battery voltage (BV)
- barometric pressure (BP)

The barometric pressure is currently monitored on BLM stations only. A blank data address is used on FS stations to retain commonality of data format. There is also capability to add other weather measurements in the future by adding the instrument, cabling, and signal conditioning circuitry.

The RAWS stand alone. No commercial power or telephone connections are used. The stations can be installed and activated in approximately 3 hours by two experienced technicians. RAWS do not require repeater stations or local base/master stations. The only repeating link is via the GOES, which is part of the total National Environmental Satellite Service (NESS) data collection system (DCS). Figures 1 and 2 are pictures of the first installed RAWS. Figure 3 is a schematic representation of RAWS.



Figure 1.--Installation of the first RAWS unit required 2-1/2 hours. The 20-foot sensor mast can be easily pivoted upward for installation and downward for easy access to windspeed and wind direction sensors.



Figure 2.--The solar-powered RAWS unit installed at the Honolulu International Airport. RAWS meteorological data were compared to those of a nearby NWS monitoring site.

BACKGROUND

The small weather stations used by the Forest Service and BLM have traditionally been located outside ranger stations or similar offices. Once or twice a day someone dutifully treks to the station, observes and records instrument readings, and telephones or radios the data to some central or sub-central recording office. The data may then be entered, through a suitable terminal, into the Administrative Forest Fire Information Retrieval and Management System (AFFIRMS) computer system. AFFIRMS then calculates the localized fire danger rating, based on those and other data, in accordance with the National Fire-Danger Rating System (NFDRS) methods. Land managers can then plan the next day's activities, such as fire crew positioning, prescribed burn actions, etc., for their area of responsibility, from the fire danger potential and other considerations.

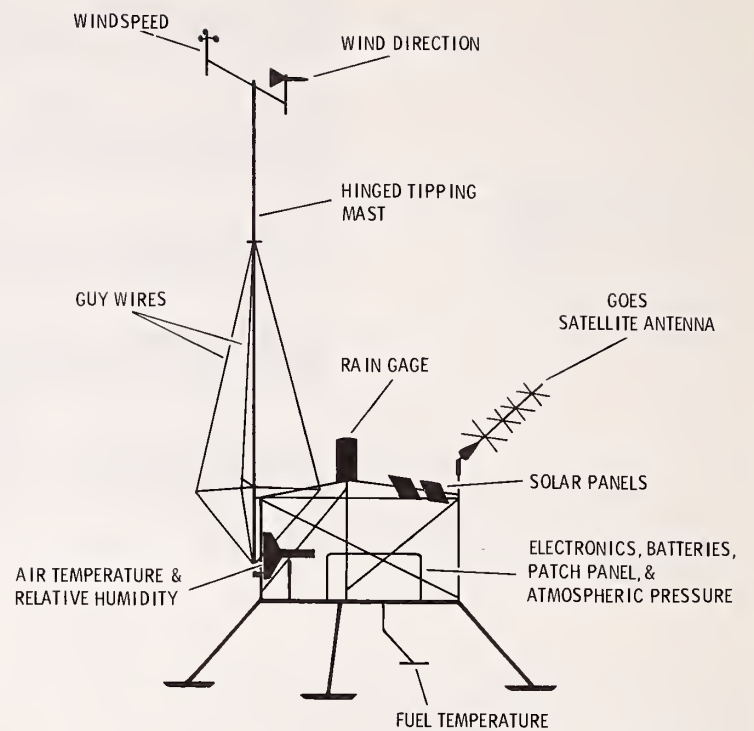


Figure 3.--Schematic representation of RAWS.

Unfortunately, the weather at a ranger station is not always correlative with or even indicative of weather on top of a mountain, over the hills, or in other pertinent areas. Accessibility, cost of personnel and transportation, and time differences in readings have essentially precluded the use of nonautomatic stations for securing weather data in remote locations. Further, during fires or other abnormal situations, people are not always available, even at ranger stations, to read the instruments and report the weather--when it is most urgently needed.

Stations (other than the GOES-based RAWS) that could be designed for remote automatic operation include telephone links, VHF or other radio systems, and meteor-burst systems. The cost of telephone line installation to most remote sites would eliminate their consideration. Reliability of phone lines, especially during fires when poles may be burned down, would also raise considerable doubts regarding their suitability. The esthetic value of scenic areas may also be adversely affected by poles and lines.

Radio link systems at VHF or higher bands require line of sight from the remote station to the base station or to a repeater, which in turn needs line of sight to the base. This restricts locations of remote sites and/or imposes the complexities of multiple repeater hops. Electromagnetic interference can be a difficult problem, especially at choice repeater sites that may already be loaded with repeaters and remote transmitters. Frequency allocation approval is another significant hurdle since frequency spectrum usage is stretched to capacity. Radio link systems also become clusters of systems, of perhaps 4 to 8 remote stations, a few repeaters and a base station. The clusters then require a person at the base station to gather the relayed data and send it to another center for entry into AFFIRMS. In very remote locations, such as interior Alaska, the radio system would be questionable in both performance and cost.

Meteor-burst communications systems utilize the ionized trails of meteors to effectively "bounce" radio frequency transmissions over great distances (up to 500 miles [804 km] or so). The usable time of an ionized trail is short, but it is often sufficient to establish a two-way path with a duration adequate for data bursts that could contain weather data. Experimentation has arrived at the statistical probabilities of success, number of interrogations, etc., for various parts of the western United States and Alaska at different times of the year. A meteor-burst system is in use for snow measurements. At the time of selection of the RAWS-GOES, the meteor-burst system was not operational; planned snow measurement sites were not compatible with fire weather sites; the remote stations were larger (some requiring commercial power); and there were no cost or performance advantages. Operation was also limited to the western United States and Alaska.

In 1975 the FS began investigating the use of data collection platforms (DCP's) working in conjunction with the GOES as a means for automatically gathering weather data from remote sites. (The DCP contains the data collection/storage/transmission electronics for the RAWS.) A data collection platform using GOES was being developed by LaBarge Electronics for the U.S. Geological Survey (USGS) for automatic transmission of water levels in rivers, reservoirs, and lakes. Technical discussions were held with LaBarge engineers on DCP design and adaptability to weather station use. Discussions and facility tours were made with NESS at the World Weather Building (WWB) data processing system and the Wallops Island, Va., command and data acquisition station. The FS and BLM engineers had initiated the coordination process. It had also been determined that a GOES-based RAWS would not have the disadvantages of the other types of stations.

RAWS went through three iterations to arrive at its present configuration: experimental, prototype, and field evaluation (now operational) configurations. Figure 4 shows the prototype configuration. In 1976 the FS set up and operated two experimental RAWS using basic weather instruments. (A later version using selected weather instruments and new signal conditioning was operated for a short time in 1977.) In 1977, the BLM set up and operated two prototype RAWS, procured as entire stations from LaBarge. In 1978, FS and BLM engineers, working with LaBarge engineers, developed requirements for 10 field evaluation units. The field evaluation units were based on experience with the experimental and prototype stations and represented the consolidated and coordinated recommendations of the authors. The stations also met the data requirements of the RAWS Steering Committee and the NFDRS Implementation Team, established in January 1978.

RAWS DESCRIPTION AND OPERATION

The RAWS consist of seven primary parts: (1) tower assembly, (2) sensors, (3) signal conditioning unit (SCU), (4) sensor interface assembly, (5) convertible data collection platform (CDCP), (6) antenna, and (7) power source.



Figure 4.--Prototype configuration of the RAWS unit.

1. Tower assembly.--The tower assembly consists of the basic structure, a mast, guy wires, cable raceways, and the electronic enclosure. The basic structure is a triangular, prism-shaped tripod supported on tundra pads. Each of the three legs is adjustable in 1-inch increments, from 1 inch to 16 inches (2.54 cm to 40.6 cm) to allow for tower leveling. All horizontal members, all diagonal members, and all tundra pads are interchangeable. The vertical members of the triangular prism structure form into part of the legs and may be positioned in any of the three corners, depending upon the desired location. The basic structure is designed from 2-inch and 2.25-inch (5.08-cm and 5.72-cm) aluminum pipe for strength and light weight.

The two-piece, detachable mast extends 20 ft (6.1 m) above the ground plane when the adjustable feet are in their center position. The mast is hollow (2-inch [5.08-cm] aluminum pipe) to conceal and protect the sensor cables coming from the top of the mast and is lightweight for ease of handling. The mast is designed to be lowered away from the tower by removing one bolt and "walking" it away from the basic structure as it pivots on its lowest point of connection, thus allowing direct access to the sensors mounted at the top of the mast. An aircraft-type support cable is permanently attached to the mast from the vertical member of the basic structure to hold the mast in a horizontal position 4 ft (1.22 m) above the ground while it is in the lowered position. This permits safe

and ready access to the wind instruments for installation and trouble shooting. It is an innovative, marked improvement from the need to climb towers at the risk of life, limb, and wind instruments. The tower is stable and designed to withstand wind loads of 100 mi/h (161 km/h).

The guy wire assembly braces the mast, especially during the high winds. The guy wires are designed to be an integral part of the mast, so they do not require removal during the raising or lowering of the mast and are spaced at 120-degree angles from each other. The lower ends attach just above the lower pivot point of the mast while the upper ends attach about 6 ft (1.8 m) below the top of the mast. Each wire has a turnbuckle for tightening or loosening the wire and a wingnut to lock the turnbuckle after adjustment. The guy wires are aircraft-type cables specifically designed for high-tension applications.

The cable raceway holds and protects the sensor cables routed from each sensor to the tower enclosure. The raceways are attached to the tower by pipe clamps that are readily removed or installed. Each raceway has a snap-on cover for fast removal or installation.

The tower enclosure is a NEMA-type enclosure attached to the tower by a UNISTRUT platform. The enclosure, after installation, contains the CDCP, SCU, barometric pressure sensor, SCU/interface chassis, and two batteries. The enclosure is vented to prevent moisture buildup and is accessible by standing inside the basic tower structure.

2. **Sensors.**--There are seven standard sensors in the remote meteorological station:

a. **Precipitation sensor.**--The precipitation sensor measures precipitation in the form of rain. An 8-inch (20.3-cm) diameter orifice collects the water, which is directed through a funnel to a tipping bucket mechanism. A mercury switch closes each time the bucket tips, thereby providing a momentary switch closure. The tipping bucket mechanism consists of two small containers positioned to collect the precipitation as it drains through the funnel. When 0.01 inch (0.025 cm) of precipitation has been collected, the bucket tips, draining the collected water out the bottom of the gage and positioning the second bucket to begin collecting precipitation.

b. **Windspeed sensor.**--The windspeed sensor is a 3-cup anemometer designed to have a low velocity threshold. The metal cup assembly includes a permanent magnet that operates a sealed magnetic reed switch on the nonrotating part of the assembly. As the cup assembly rotates, it closes the reed switch, providing switch closures to the windspeed translator module. The frequency of the switch closures is proportional to the windspeed. The anemometer is mounted on the crossarm at the top of the 20-ft (6.1-m) mast and interfaces with the windspeed translator module through the signal cable.

c. **Wind direction sensor.**--The wind direction sensor is a lightweight airfoil metal vane. The vane is coupled to a precision microtorque potentiometer for low-threshold operation. Output of the wire-wound potentiometer varies proportionally with wind direction. This output is produced as the wind direction module applies a precise voltage to the potentiometer and the potentiometer output becomes a voltage proportional to the wind direction. The wind direction vane is mounted on the crossarm at the top of the 20-ft (6.1-m) mast and interfaces with the wind direction module through the signal cable.

d. **Air temperature sensor.**--The air temperature sensor is a solid-state linear thermistor and precision resistor network, potted in a shockproof 3/8-inch (0.95-cm) (outside diameter) stainless steel housing. The sensor is positioned in a vane-aspirated radiation shield to reduce the effects of solar radiation upon the temperature data. The air temperature is sensed with a linear three-element thermistor. The output of the sensor is a resistance proportional to the ambient temperature. The air temperature sensor is positioned 4 to 5 ft (1.2 to 1.5 m) from the ground surface and is coupled to the air temperature module through the air temperature cable.

e. **Fuel temperature sensor.**--The fuel temperature sensor is a solid-state linear thermistor and precision resistor network potted in a 6-inch x 3/8-inch (8.5-cm x 0.95-cm) dowel stick. The stick is mounted on an adjustable arm positioned approximately 10 inches (25.4 cm) above the ground plane. The arm is positioned on the south side of the tower to insure that the stick is in direct sunlight. The sensor stick is attached to the arm with cable clamps that support the sensor stick as well as insulate it from the metal arm. The temperature of the stick is sensed with the linear three-element thermistor. The output of the sensor, a resistance proportional to the temperature of the fuel stick, is coupled to the fuel temperature module through the fuel temperature cable.

f. **Relative humidity sensor.**--The relative humidity sensor is a polymer, thin-film capacitor contained in the air temperature sensor housing for protection. The sensor is also protected by a 216 micron sintered bronze filter. The thin-film capacitor is composed of an upper and lower electrode with an organic polymer dielectric about 1 micron thick. Water vapor is absorbed into the polymer after the vapors pass through the upper metal electrode. The result is that the capacitance changes linearly as the moisture increases or decreases. The sensor output is coupled to the relative humidity module through the relative humidity cable. The relative humidity sensor is positioned on a cross-arm approximately 4 ft (1.2 m) above the ground plane.

g. **Barometric pressure sensor.**--The barometric pressure sensor is a sensitive aneroid barometer that provides a resistance output proportional to the barometric pressure. It utilizes an evacuated bellows that is sensitive to changes in absolute pressure and is mechanically connected to the arm of the potentiometer. The barometric pressure sensor is housed inside a weather-proof enclosure to protect the sensor. For the RAWS application, the complete barometric pressure assembly is mounted inside the tower enclosure.

3. **Signal conditioning unit (SCU).**--The signal conditioning unit is the housing for the sensor signal conditioning modules. Each of the sensors has a signal conditioning card in this unit. Each sensor module is plugged into the card rack, which contains card-edge connectors that interface input/output functions to each of the modules. Besides the sensor modules, the SCU also contains a battery monitor module that supplies analog data proportional to the system battery voltage. All sensor modules, except precipitation, provide outputs scaled from 0-5 volts analog over the dynamic range of the sensor. The precipitation module stores the number

of times the tipping bucket has tipped, hence, the measure of total rainfall. The precipitation module counter circuit can be cleared to all zeros by the accumulator display.

4. Sensor interface assembly.--The sensor interface assembly is comprised of the sensor cables and the sensor/SCU interface chassis. The cables are cut to length so that there are not excessive cables to store. Each cable is marked with its sensor name (example - WINDSPEED) for fast identification. The cables are vinyl coated to provide protection from the environment.

The cables are interfaced to the SCU through the interface chassis, which provides a junction point for all sensor cables. The chassis is clearly marked to identify each sensor cable mating connector. The sensor interface chassis is mounted on the enclosure wall for easy access and visibility.

5. Convertible data collection platform (CDCP).--The CDCP is a completely microprocessor-controlled data acquisition system. It accepts the sensor data at the specified programmed times, converts it from analog to digital (if it is analog), or accepts it directly if it is digital, and stores the digitized data in memory for subsequent retrieval and data transmission. For RAWS application the CDCP is programmed to receive and process the sensor data each hour and to transmit the stored data every 3 hours. Therefore, each data transmission will contain three data samples from each sensor.

The CDCP is designed to go into a lower power, minimum operation mode during the time when data are not being acquired, processed, or transmitted. The low-power mode draws an insignificant amount of current compared to the charging rate of the batteries.

The CDCP controls the application of power to all sensors except the windspeed, wind direction, and precipitation sensors, which remain powered up continuously. The CDCP is connected to the SCU with the SCU/CDCP cable. The CDCP is positioned in the tower enclosure.

6. Antenna.--The antenna is specifically designed for transmitting to the GOES satellite. It consists of two quadrature-phased cross-element yagi antennas mounted on a common boom. The antenna is mounted on the tower on the extended vertical section of the basic structure and connects to the CDCP through the antenna cable. The position does not interfere with airflow to the wind sensors.

7. Power source.--The power source consists of two gel-cell batteries connected in parallel and charged by two solar panels with regulators. The solar panels are positioned on a horizontal member of the basic tower. The horizontal member is positioned so that the panels receive direct sunlight and are not shaded by any object on the tower. Sealed 12V automotive batteries have also been used successfully in some installations.

Support equipment.--The support accessories for the RAWS include the CDCP test set and the tipping bucket accumulator display. These items are not a permanent part of the RAWS but are required in setting up and maintaining the station.

The test set is used to activate, time, enter constants into the CDCP, and to read the data as stored in the CDCP memory. The test set is essential for troubleshooting and also for manipulating the CDCP and its memory to utilize the flexibility of the system.

The tipping bucket accumulator display is used to simulate the precipitation sensor, to monitor the precipitation module in the SCU, and to reset or clear the counter circuit on the precipitation module.

The DCP contains the "brains" for the RAWS. The microprocessor controls power, timing, input, storage, and output. One must be fluent in analog, digital, binary, hexadecimal, ASCII, RF, logic, power, modulation, and instrumentation circuits/codes to fully understand RAWS operation.

The activation sequence requires setting the timing precisely using WWV reference, entering station ID and operation mode constants into memory, entering constants unique to the particular setup, and adjusting the data buffer pointer to the desired position.

GOES DESCRIPTION AND OPERATION

The GOES-DCS system is shown in figure 5. The GOES and the geostationary orbit are shown in figure 6. Note that the GOES accomplishes many functions in addition to the data relay from DCP's.

A summary of DCP characteristics is provided in appendix 1.

Data are acquired in analog (except for digital measurements), converted to digital, and stored in binary form in DCP memory. The test set converses with the DCP and test set user in hexadecimal. Just prior to transmission, the non-return-to-zero (NRZ) binary data are converted to Manchester coding for transmission. The 401.XXX MHz transmitter is biphasic shift keyed ± 60 degrees from the nominal carrier phase reference to correspond to the one or zero Manchester level of the data. Following an unmodulated carrier transmission, some specially coded house-keeping sequences and station ID, the data bits are transmitted at 100 bits per second to the GOES.

In normal FS/BLM operation, the RAWS are programmed and set up to acquire and store data every hour and transmit every 3 hours. The microprocessor will follow this approximate sequence of events: every 15 minutes add 1 count to the data acquisition and transmit interval counters. If the data acquisition count matches the programmed count (4 for 1 hour), power up the sensors (except those on continuous power), sample the outputs, and store the new data in memory, replacing the oldest data. If the data transmit interval count matches the programmed count (C or 12 for 3 hours), three hourly data sets will be transmitted following the data update. After completion of the actions required and updating counters and pointers, the microprocessor puts the station back into a low-power drain, semisomnus mode, and waits for the next 15 minutes to pass.

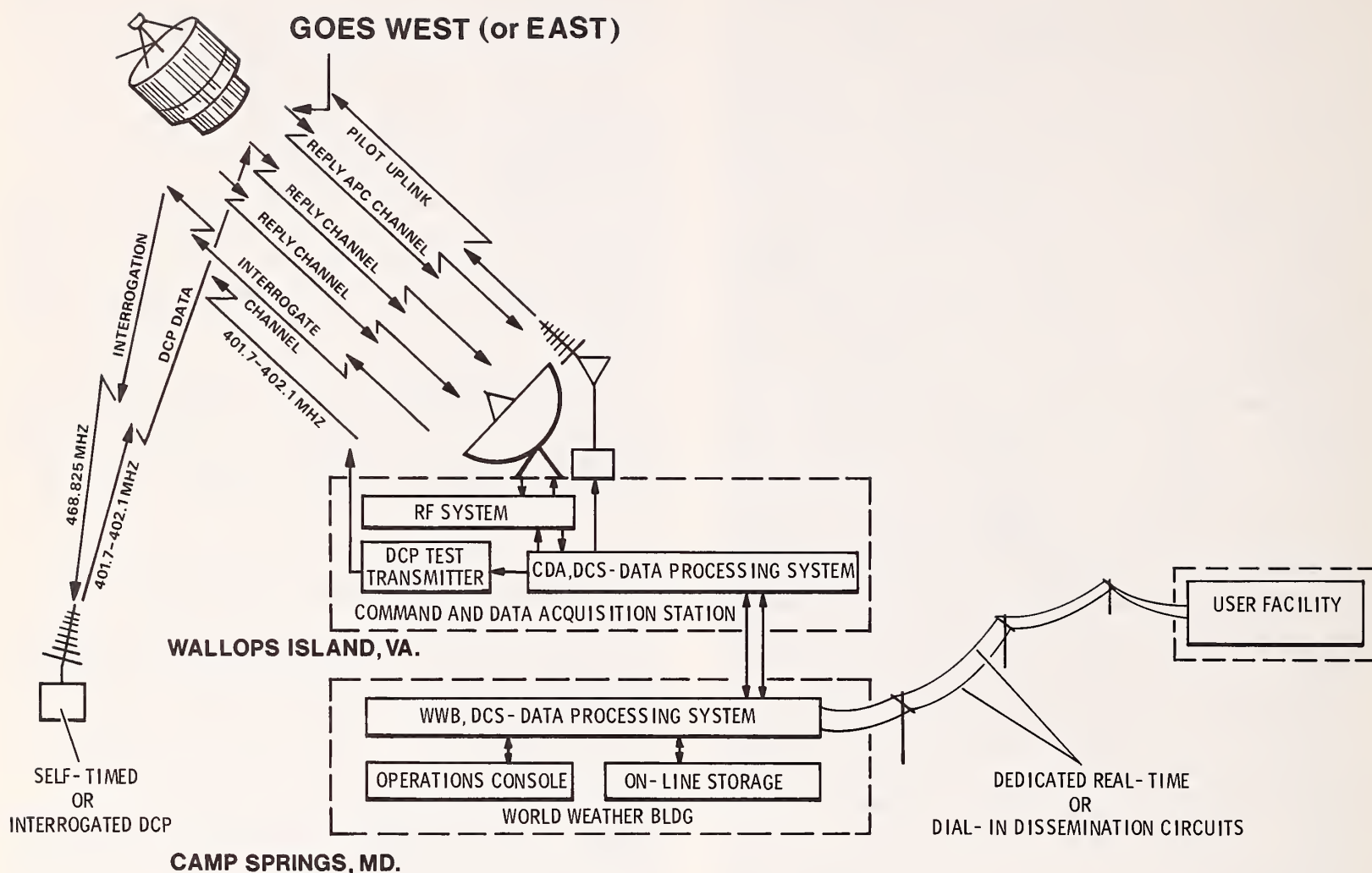


Figure 5.--GOES/DCS system description.

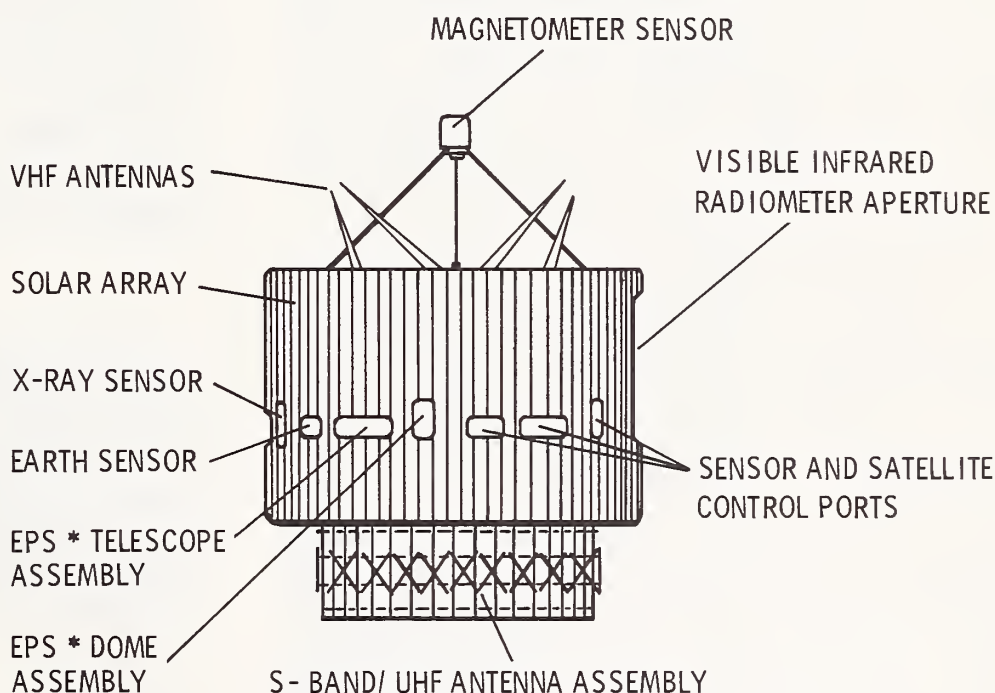
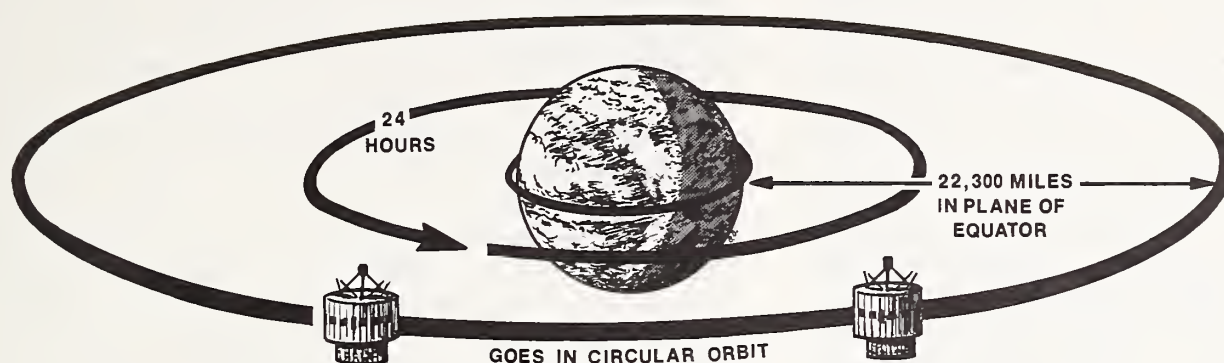
The GOES-DCS is a synchronous satellite based communications system for collecting geophysical data from virtually any point on the Western Hemisphere. Although this system description is concerned only with the DCS portion of the GOES system, the spacecraft (S/C) and the Command and Data Acquisition Station (CDA) have several missions. The GOES system provides the following functions:

1. The VISSR system has a visible and infrared spin-scan radiometer that views the earth's cloud cover and surface and transmits the data to earth.
2. The stretched VISSR system transmits processed VISSR data to data utilization stations via the GOES satellite.
3. The WEFAX system transmits weather facsimile cloud cover pictures to users via the GOES satellite. (Seen on TV weather forecasts.)
4. The SEM system monitors the space environment and transmits particle energy and trajectory data to the Boulder, Colo., Space Disturbance Forecast Center.
5. The DCS system relays data from both self-timed and interrogated DCPRS units to the CDA. The DCPRS units interface with ships, buoys, rain gages, river level gages, seismographs, remote weather stations, etc.

6. The CDA command and telemetry system enables the CDA to configure the satellite and monitor its status.

A complete communications link from a set of remote sensors to a user employing the GOES/DCS normally will consist of the following elements:

1. A DCP--this unit converts sensor data to a 100 bit/second, Manchester-encoded serial data stream, phase modulated on a UHF (402 MHz) carrier at an EIRP of approximately ± 50 dBm.
2. A UHF to S Band transponder in synchronous earth orbit--this subsystem of the GOES S/C receives the DCPRS signal, up converts it to 1694 MHz, and retransmits the signal to an earth receiving system.
3. The CDA station--this is the GOES earth station located at Wallops Island, Va. Signals relayed through the S/C are received by a large parabolic antenna, amplified, down converted, demodulated, and multiplexed together with nine other DCPRS channels. A 16 bit mini-computer receives and formats the data for transmission over dedicated, conditioned, leased land lines to the DCS/DPS.
4. The DCS/DPS--this is a large scale computer system in the World Weather Building, Camp Springs, Md. (NESS offices), which receives all DCPRS data from the CDA. The DCS/DPS carries out the multiple functions of



* (Energetic Particle Sensor)

Figure 6.--Geostationary (or synchronous) orbit.

scheduling all activity within the DCS, checking data for errors, disseminating the data, maintaining performance histories on individual DCPRS units, and routinely testing the system for failure identification. Users may communicate with the DCS/DPS over either dedicated realtime land lines or via one of the two dial-in (user demand) circuits operating at 300 or 1200 baud.

5. A data terminal--this is the final hardware element required to complete the normal communications link from a DCPRS. The terminal can be as simple as an ASR-33 teletype or as complex as a postprocessing computer system, depending on the volume of data and processing requirements.

EVALUATION

RAWS sites were selected in various States to cover a wide range of climate and geography. The States were selected by Cooperative Fire Protection (CFP), State and Private Forestry (S&PF) of the Forest Service, with cooperative agreements to cover the subsequent operation and maintenance of the stations. The RAWS were placed in Honolulu, Hawaii; Plains, Mont.; Hill City, Minn.; London, N.H.; and Tallahassee, Fla. All were located near or adjacent to an existing manual station. The five stations were set up and activated during June 1978, with a planned evaluation period running to about October 1, 1978. Data from the RAWS were compared with data from the manual stations during that time. The data were retrieved from the NESS computer via dial-up lines at the site location and at the Boise Interagency Fire Center (BIFC).

RAWS sites were selected in Alaska on the basis of the need for data from particular remote areas. Fire Management Alaska utilized information from a previous climate study, National Weather Service, and a knowledge of the fire problem areas in reaching their location decisions. Elevation was an important factor in station placement. Before RAWS, meteorological data were usually obtained at locations where BLM had fire operations. The fire bases were usually located at low elevation and frequently near water. With freedom to pick an ideal location, RAWS sites were set up at increased elevation in representative fire fuels, away from water.

The Alaska sites selected were:

Sites	Latitude	Longitude	Elevation	
			Feet	Meters
Jade Mountain (JDM)	67°30'	158°00'	500	152
Wein Lake (WNL)	67°30'	150°45'	690	210
Salmon Trout (SMT)	67°00'	141°10'	1800	549
Kiwalik (KWL)	65°25'	162°10'	700	213
Innoko (NKO)	63°25'	158°50'	210	64

During installation of the 10 evaluation stations, several problems were encountered and resolved. Following initial installation, three sensors and one DCP failed during the evaluation period. (The evaluation period was June to October, comparable to a "normal" fire season.) Based on the small evaluation sample of 10 stations, this would indicate a return trip to 40 percent of the stations over a season.

The five stations situated adjacent to manual stations met tolerances for all measurements except relative humidity (RH). The RH readings from RAWS were consistently lower than those from the manual stations. The RH sensor has since been incorporated into the air-aspirated air temperature sensor housing and calibration procedures have been improved. (This modification appears to have resolved the problem, but it is still being watched.) The evaluation concluded that RAWS are reliable and can be considered operational. (The 10 evaluation units are presently being used as operational units.) A detailed report of the evaluation is available.¹

Subsequent to the 10-station evaluation, 10 more stations were procured (five by FS and five by BLM) and are in operational use. These stations have operated satisfactorily and confirm the initial evaluation conclusions of reliability and operational readiness.

The evaluation and operational stations have also provided opportunity to evaluate field maintenance needs and technician capabilities. It appears that a competent radio or electronics technician who accompanies experienced RAWS technicians during a RAWS installation and activation can subsequently perform basic removal and replacement of sensors, cables, and signal conditioning unit boards on his own. Without the installation experience, 1 day's training should suffice for that level of maintenance. Some consultation might be necessary if the problem must be traced to a board or sensor. But, if adequate spares are available, the problem measurement's sensor and board can both be replaced negating the need for complete isolation/confirmation.

For complete installation/activation, including DCP programming and test set usage, a 3-4 day course developed by the senior author is recommended.² Trainees must be experienced electronics technicians (at least GS-7 level); and some digital experience is highly desirable. A step-by-step guide can then be followed as an aid to installation/activation.³

Depot-level maintenance plans have also been developed for various numbers of fielded RAWS and are available from Boise Interagency Fire Center (BIFC).^{4 5}

DATA RETRIEVAL

Weather data transmitted from any of the RAWS sites are available from the NESS computer to any site having a suitable terminal and telephone lines, almost instantaneously after transmission. The user pays only for the cost of the phone call and needs only a simple 300 baud, ASCII terminal to complete the data acquisition link. The data from any site or sites are thus available at any location or locations.

¹Vance, Dale, and J.R. Warren. 1978. A remote automatic weather station for fire weather monitoring--development and test report. Boise Interagency Fire Center, Boise, Idaho.

²Warren, J. R. 1979. RAWS course outline. Boise Interagency Fire Center, Boise, Idaho.

³Warren, J. R. 1979. DCP installation/activation procedure. Boise Interagency Fire Center, Boise, Idaho.

⁴Warren, J. R. 1978. Implementation plan for remote automatic weather stations (RAWS) for USFS users. Boise Interagency Fire Center, Boise, Idaho.

⁵Warren, J. R., and Duane Herman. 1979. Implementation plan for remote automatic weather stations (RAWS). Boise Interagency Fire Center, Boise, Idaho.

The data from NESS is presented in ASCII as either hexadecimal letters aa through oo (ASCII column 5) for LaBarge stations, or as decimal numbers 000 through 255 (ASCII column 4) for Handar stations. In both cases there are 256 levels (8 bit encoding) to represent zero to full scale. The appropriate look-up table must be used to manually convert either type printout into usable data. Digital data are treated differently. For additional details, users should obtain descriptive material by the authors^{6 7} and should contact one of the authors for explicit, detailed instructions.

Because many FS, BLM, and State users utilize and have access to the AFFIRMS, an automatic data transfer system from the NESS computers to AFFIRMS is being implemented. When completed, all RAWs data will be readily available via the existing AFFIRMS without the need for separate user terminal access and phone calls to NESS. Meanwhile, data are daily being entered manually into AFFIRMS.

Data may also be retrieved from the satellite by the user's own earth station. The stations consist of a 5-meter (approximately 15-ft) parabolic antenna, a 6-foot (1.8-m) equipment rack (containing receiver, demodulator, and minicomputer), and a user terminal. Stations have been installed and are in operation by Colorado State University, Fort Collins; California Department of Forestry, Sacramento; and BLM, Boise, Idaho. The stations receive from only one satellite (unless a second antenna system is installed). The output also contains diagnostic information for individual RAWs. The earth stations cost approximately \$50,000.

RAWS AVAILABILITY

There are currently two suppliers of FS/BLM RAWs: LaBarge, Inc. and Handar, Inc. The 10 evaluation stations and the 10 additional stations that are all operational were procured from LaBarge. The Handar stations have a similar instrument complement, a NESS-certified DCP, and are anticipated to be satisfactory for field use. Handar DCP's have been used successfully in Bureau of Reclamation stations. Several Handar stations are on order by the FS and will be observed by FS/BLM engineers to determine their performance.

The RAWs manufactured by the two firms have the same measurement capability, but DCP's are different: a LaBarge DCP requires a LaBarge test set; a Handar DCP requires a Handar test set.

The cost of either RAWs is currently approximately \$10,000 each, depending on quantity and a few options. GSA procurement is available or is being processed for both stations. Other companies have the capability to supply similar stations, but, at this time, do not have a RAWs meeting FS/BLM requirements.

Details on the formats and procurement considerations are described in a special report by the authors, which has had wide user distribution.⁶ The reference should be reviewed prior to initiating procurement action.

Operation of RAWs requires a channel and time slot assignment from NESS and a frequency allocation from the user agency.

RAWS TECHNOLOGY

The RAWs uses satellite communications, solar energy, microprocessor control, and integrated circuits, coupled with more traditional electronics and meteorological sensors. Twenty-five years ago there were no man-made satellites in orbit, no microprocessors, and no integrated circuits. Solar panels were laboratory or experimental--not practical, working units. These technologies are now used routinely and in the case of RAWs sit alone in some very remote locations and perform reliably.

POTENTIAL OF RAWs

RAWs has the potential for Nation-wide use as part of the National Fire-Danger Rating System. It is ideal for that application because the stations can be set up at any desired location and the data automatically entered into the AFFIRMS. This specific application has been the impetus to the development of RAWs.

RAWs can also be set up in a grid or network of stations to provide detailed weather data over a specified area. Areas with special considerations--high values, frequent fires, daily wind shifts, and so on--might warrant such a network. A network of stations has been proposed for the Firescope area in southern California. A network might also be used for research of certain weather or other characteristics of an area.

Individual stations or a few stations can be used to determine the weather conditions prior to and during prescribed burns, spraying operations, and so on. A simple check of the weather in the area via RAWs may eliminate the need to drive considerable distances to manually check conditions. Thus energy as well as time and expense may be conserved. Likewise, false starts can be reduced and better crew utilization achieved.

The use of properly maintained and calibrated RAWs offers the potential for better standardization of weather measurements. Work with RAWs has indicated that there are wide variations in the use, calibration, maintenance, and accuracy of manual stations.

RAWs are readily adaptable for any remote, automatic data gathering need--not just weather. Various types of instruments and sensors could interface with RAWs to provide data from a variety of sources and areas. (The use of GOES must be related to environmental needs, which includes a lot of applications.)

RAWs may be used in an interrogate mode instead of on a self-timed schedule. Under the interrogate mode, data can be acquired on signal, schedules changed, data collection frequency-related to conditions, and so on. (The interrogated stations cost more than the self-timed stations).

⁶Warren, J. R., and Dale Vance. 1979. Remote automatic weather station (RAWs) procurement, use configurations, and data formats. Boise Inter-agency Fire Center, Boise, Idaho.

⁷Warren, J. R. 1979. RAWs data acquisition. Boise Interagency Fire Center, Boise, Idaho.

An emergency alarm system may be included that will cause the RAWS to transmit on the emergency channel under certain conditions or when selected parameters exceed specified values. Water levels, high winds, high or low temperatures, and so on, could all serve as alarm indicators.

Fire-weather forecasters have identified a need for portable RAWS that could be readily set up in remote locations around large fires. These stations would be simpler than conventional RAWS and provide basic measurements of the local weather, including the fire's influence. The portable RAWS could be readily adapted with a minimum of development cost from the current RAWS technology and components.

RAWS is readily adaptable for use with other systems. For example, properly located RAWS coupled with the automatic lightning detection system (ALDS) could indicate the probability of lightning fire starts. That prediction could then be used to determine the need for infrared (IR) detection flights over the area of concern. The three systems working together could help land managers determine the probability of ignition, and the number, location, and size of lightning-caused fires. Properly located RAWS would also be invaluable to those using fire rate-of-spread models for ongoing wildland fires.

REFERENCES

- LaBarge Earth Resources.
[n.d.] RAWS to assist in National Fire-Danger Rating System. Monitor, vol. 1, No. 4. LaBarge Earth Resources, Tulsa, Okla.
- Warren, J. R.
1978. Remote automatic weather station (RAWS) status. Unpubl. rep., USDA For. Serv., Boise Interagency Fire Center, Boise, Idaho.
- Warren, J. R.
1978. Remote automatic weather stations (RAWS). Unpubl. Rep., USDA For. Serv., Boise Interagency Fire Center, Boise, Idaho.
- Warren and Baker.
1977. Remote meteorological stations for NFDRS. Unpubl. rep., USDA For. Serv., Boise Interagency Fire Center, Boise, Idaho.
- USDA Forest Service.
1978. Bend Lab has new station. USDA For. Serv., Pac. Northwest For. and Range Exp. Stn., PNW News. Portland, Oreg.

APPENDIX I

DCP CHARACTERISTICS

Item	Specification
Transmit frequency	401.7 to 401.85 MHz
Channel spacing	1.5 kHz
Frequency stability, long term	1 p/m per year
Spurious outputs and harmonics	-50 dB (below carrier)
Modulation	Phase shift keyed (PSK)
Phase shift magnitude	$\pm 60^\circ$ ($\pm 10^\circ$) with a transition time of 20 (± 10) microseconds
Output bit rate	100 \pm 1 bit/s, Manchester encoded
Output format	5 seconds of clear carrier, 2.56 seconds of Manchester encoded clock pulses, 15 bit maximal linear sequence (MLS) of 100 0100 1101 0111, 31 bit CDCP ID address up to 2,000 bit data message, and three ASCII EDT (end of transmission) pulses
Transmitter fail safe feature	Transmitter will automatically power down after a 90-second transmission interval (independently of microprocessor control)
Coding	Data encoded into eight-bit bytes to ASCII format
Parity	Even or odd (selectable)
Message intervals	Selectable (by constant entered from test set) from 15 min to 63 h, 45 min (up to 255 increments) in 15 min increments
Message interval accuracy	1 p/m per year
Accuracy of initial transmission	± 1 second (controlled by operator)
Emission classification	1.5F9/5

APPENDIX 2

RAWS MEASUREMENT SPECIFICATIONS

- Cumulative Precipitation (Precip.)**
 Range: 0.01 to 99.99 inches
 Accuracy: ± 0.01 inches (rainfall intensity up to 2 inches in 1 h)
- Windspeed**
 Range: 0-100 mi/h
 *Accuracy: ± 2.5 percent - typical
 ± 5.0 percent - maximum
 Averaged: 2 min time - weighted
 Threshold: 1 mi/h
- Wind Direction (WD)**
 Range: 0-540°
 *Accuracy: ± 5.5 percent - typical
 ± 9.2 percent - maximum
 Averaged: 2 min time - weighted
 Threshold: 1 mi/h windspeed
- Fuel and Air Temperature (FT and AT)**
 Range: -30 to +70° C
 Accuracy: $\pm 1^\circ$ C (± 1 percent) - typical
 $\pm 2^\circ$ C (± 2 percent) - maximum
- Relative Humidity (RH)**
 Range: ± 3 percent - typical
 ± 5 percent - maximum
- Barometric Pressure**
 Range: 24 to 31 inches of mercury
 Accuracy: ± 0.070 inches of mercury (± 1.0 percent) - typical
 ± 0.100 inches of mercury (± 1.4 percent) - maximum
- Battery Monitor**
 Range: 8.9 to 15.0 volts DC
 Accuracy: ± 0.2 VDC - typical
 ± 0.3 VDC - maximum

*A tolerance of \pm one table value applies for low range readings (\pm bit A/D converter limit).

Warren, John R., and Dale L. Vance

1980. Remote automatic weather station for resource and fire management agencies. USDA For. Serv. Gen. Tech. Rep. INT-116, 11 p. Intermountain Forest and Range Experiment Station, Ogden, Utah 84401.

A weather station that operates automatically in remote areas, without power or communication lines, has been developed and is now commercially available. Remote Automatic Weather Stations (RAWS) transmit precipitation, windspeed, air temperature, fuel temperature, humidity, and barometric pressure data via satellite. Data are received at Wallops Island, Va., and stored at the World Weather Building, Maryland. Data may be acquired by direct dialing or through the AFFIRMS fire forecasting program of the USDA Forest Service.

KEYWORDS: weather stations, meteorological data acquisition, fire weather, environmental data, satellite data transmissions

The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 273 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

Field programs and research work units of the Station are maintained in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

